RESEARCH DEPARTMENT

The screening effect of the North Downs in Surrey on distant Band I transmissions

RESEARCH REPORT No. K-170

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

THE SCREENING EFFECT OF THE NORTH DOWNS IN SURREY ON DISTANT BAND I TRANSMISSIONS

Research Report No. K-170

(1964/12)

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SUMMARY

Simultaneous field strength measurements of two distant Band I transmissions were carried out at two receiving sites within a few miles of each other. The sites were so chosen that while one was free of any immediate terrain obstruction, the other lay in the shadow of a range of hills. The measurements show that the ratio of the field strengths at the two receiving sites is approximately constant under varying propagation conditions, and that additional protection against co-channel interference is given to areas screened by hills. Such additional protection can be taken into account when planning a Band I television service to an area screened by hills.

1. INTRODUCTION

The demands on the spectrum available for television broadcasting in Band I are such that, if the BBC is to provide a national service, the same channel must be shared by a number of transmitters. If mutual co-channel interference between transmitters is to be kept within acceptable limits, the transmitters must not be spaced closer than a minimum distance apart, the distance depending upon the effective radiated power (e.r.p.), the aerial heights, the terrain, the relative polarization and frequency offset.

The method used by the BBC for calculating the maximum e.r.p. for a given degree of co-channel interference is that adopted by the CCIR following the European V.H.F./U.H.F. Broadcasting Conference, Stockholm 1961,[1] in the establishment of the plans attached to the European Broadcasting Agreement. It takes full account of the parameters detailed above, although the factor for terrain is difficult to estimate. In practice it is assumed that the CCIR figure for 50% of the receiving locations is in general applicable to the rolling terrain found in many parts of Europe. Planning is then based on providing protection against co-channel interference for 90% of the time.

It is well known that hills obstruct the passage of radio waves, but the resulting attenuation which can contribute additional protection in times of normal or of abnormal propagation, is uncertain. The experiment described in this report was carried out to establish an order of magnitude for the attenuation caused by a range of hills, and to examine its variation, if any, with normal and abnormal propagation. Two transmissions were measured at each of two sites, one situated near the top of the North Downs in Surrey, and the other behind an escarpment not far away.

2. GENERAL

The first series of measurements was made during the period 1st November 1961 to 28th February 1962. The two transmissions measured were the Holme Moss television sound channel on a frequency of 48·25 Mc/s and the corresponding Sutton Coldfield channel on 58·25 Mc/s. Kingswood and Reigate were chosen as the two receiving sites. Reigate is screened by the Cockshott and Reigate Hills, and is situated 5·3 miles (8·5 km) from Kingswood. It is further from Sutton Coldfield and Holme Moss than Kingswood by approximately 5 miles (8 km).

From 26th July to 20th September 1962 a further series of field strength measurements was made on the same two transmissions. The receiving sites in this instance were Kingswood and Hookwood, the latter site being screened by Box Hill and the Buckland Hills of the North Downs. Hookwood is 8·5 miles (13·7 km) from Kingswood and 3·2 miles (5·1 km) from the original Reigate site. The distance of Hookwood from Sutton Coldfield and Holme Moss is greater than that of Kingswood by approximately 8 miles (12·9 km). The Hookwood measurements were made to ascertain whether the attenuation was maintained at this site, which is 7 miles (11·3 km) from the obstructing range of hills, whereas Reigate is only 1·4 miles (2·3 km).

The transmission path distances ranged from 114 miles (183 km) to 178 miles (286 km) and varying propagation conditions were encountered during both periods of measurements.

3. SITES AND EQUIPMENT

3.1. Sites

Fig. 1 shows the geographical distribution of the transmitting and receiving sites. Further details of these sites are given in Tables 1 and 2.

TABLE 1
Transmitting Site Details

LOCATION	FREQUENCY	E.R.P.	SITE HEIGHT a.m.s.l.		AERIAL HEIGHT a.g.l.		AERIAL HEIGHT ABOVE MEAN TERRAIN*		AERIAL POL.	LATITUDE	LONGITUDE
	Mc/s	kW	ft	m	ft	m	ft	m			
Holme Moss	48·25	25	1720	524	735	224	1046	318	V	53°31'58"N	01°51'22"W
Sutton Coldfield	58·25	25	555	169	735	224	981	299	V	52°35'59"N	01°49'57"W

* Mean terrain is the average level of the ground between the distances of 3 km and 15 km from the transmitter in the required direction.

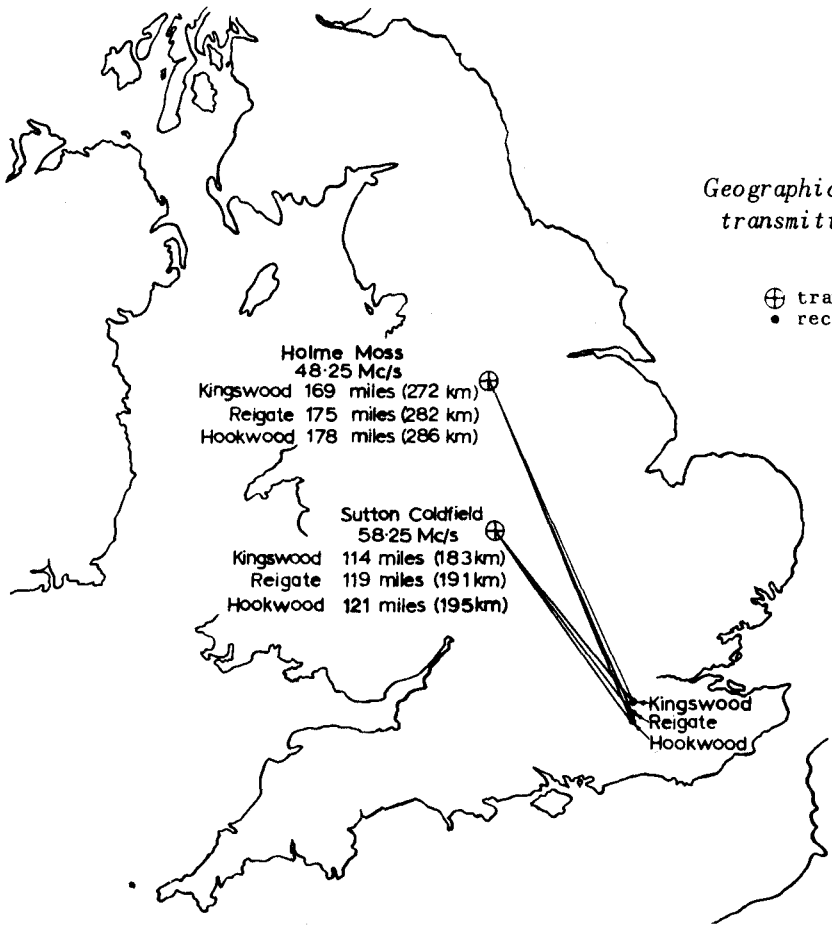


Fig. 1
Geographical distribution of transmitting and receiving sites

⊕ transmitting sites
• receiving sites

TABLE 2

Receiving Site Details

RECEIVER LOCATION	TRANSMITTER LOCATION	PATH DISTANCE		RECEIVING SITE					
				SITE HEIGHT a.m.s.l.		AERIAL HEIGHT a.g.l.		TRUE BEARING TO TRANSMITTER	LATITUDE	LONGITUDE
		mls	km	ft	m	ft	m			
Kingswood	Holme Moss	169	272	550	167	30	9·1	333·0°	51°17'20"N	00°12'50"W
Kingswood	Sutton Coldfield	114	183	550	167	30	9·1	320·5°	51°17'20"N	00°12'50"W
Reigate	Holme Moss	175	282	180	55	30	9·1	333·5°	57°12'47"N	00°11'11"W
Reigate	Sutton Coldfield	119	191	180	55	30	9·1	321·0°	57°12'47"W	00°11'11"W
Hookwood	Holme Moss	178	286	175	53	30	9·1	334·0°	51°09'05"N	00°11'15"W
Hookwood	Sutton Coldfield	121	195	175	53	30	9·1	321·5°	51°09'05"N	00°11'15"W

3.2. Equipment

The Band I superheterodyne receiver used for the measurements has been described in a separate Research Department Report.[2] The outstanding features of this receiver are its high reliability and gain stability when used over a long period of time. The intermediate frequency is 270 kc/s and the selectivity response is substantially constant over ± 5 kc/s, falling by 45 dB at ± 20 kc/s. This narrow pass-band rejects the sound carriers of other co-channel transmitters offset by 20 kc/s. The receiver has a logarithmic input/output characteristic over a range of 50 dB, but the overall gain of the receiver may be adjusted to suit the median signal by means of attenuators inserted between the signal frequency and the intermediate frequency units. A portable unit houses two receivers and supplies the power necessary to operate them.

Conventional commercial-type H aerials, mounted on separate 30 ft (9·1 m) tubular masts, were used at the receiving sites.

The recording charts were run at a speed of 6 inches (15·2 cm) per hour and recordings were made during normal television hours of transmission.

4. RESULTS

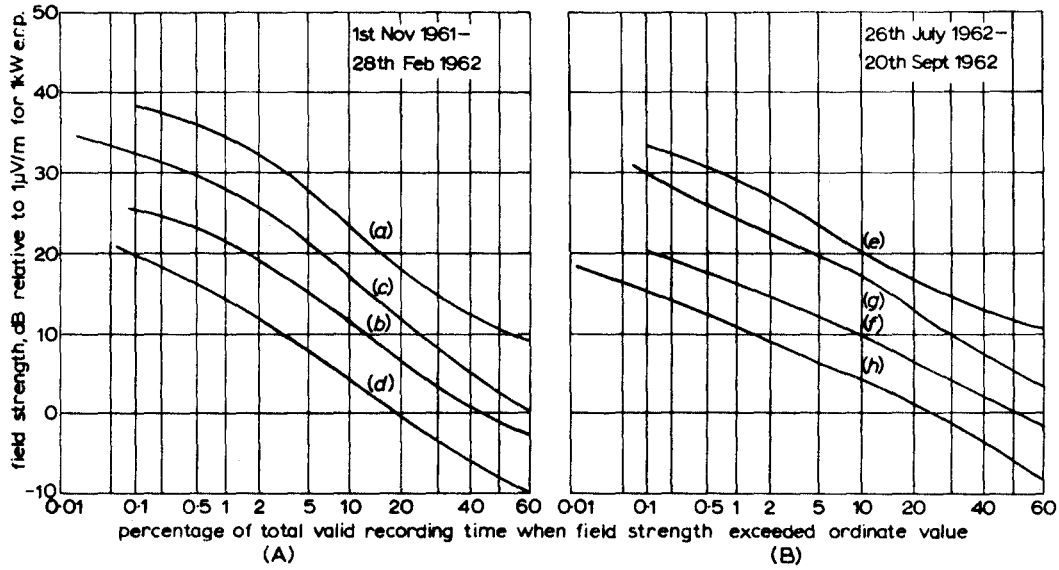
4.1. Variation of Field Strength with Time

The results of the Kingswood and Reigate measurements taken during the period 1st November 1961 to 28th February 1962 are plotted in Fig. 2(A) as field strength against percentage time for the Holme Moss and Sutton Coldfield transmissions. Fig. 2(B) gives the results of similar measurements for the period 26th July 1962 to 20th September 1962, with Hookwood replacing Reigate as a receiving site. The field strengths for selected time percentages derived from Fig. 2(A) and Fig. 2(B) are set out in Table 3.

TABLE 3

Sutton Coldfield and Holme Moss Results

CURVE (FIG. 2)	RECEIVING SITE	TRANSMISSION	DISTANCE km	FIELD STRENGTH, dB REL. TO 1 μV/M FOR 1 kW E.R.P. 0·1%	1%	10%	50%
(*a*)	Kingswood	Sutton Coldfield	183	38·5	34·5	23·5	11·0
(*b*)	Reigate	Sutton Coldfield	191	25·5	21·5	11·5	-1·0
(*c*)	Kingswood	Holme Moss	272	32·5	28·0	17·0	3·0
(*d*)	Reigate	Holme Moss	282	20·0	14·5	4·5	-7·5
(*e*)	Kingswood	Sutton Coldfield	183	33·5	29·5	20·5	12·0
(*f*)	Hookwood	Sutton Coldfield	195	20·5	16·5	10·0	0·5
(*g*)	Kingswood	Holme Moss	272	30·0	24·5	17·5	5·5
(*h*)	Hookwood	Holme Moss	286	15·5	11·0	4·5	-5·5



CURVE	RECEIVING SITE	TRANSMISSION	DISTANCE		TOTAL HOURS RECORDED	FREE SPACE FIELD FOR 1 kW E.R.P. (dB)
			Miles	Kms		
(*a*)	Kingswood	Sutton Coldfield	114	183	1024	61·6
(*b*)	Reigate	Sutton Coldfield	119	191	1029	61·3
(*c*)	Kingswood	Holme Moss	169	272	935	58·2
(*d*)	Reigate	Holme Moss	175	282	939	57·9
(*e*)	Kingswood	Sutton Coldfield	114	183	713	61·6
(*f*)	Hookwood	Sutton Coldfield	121	195	684	61·1
(*g*)	Kingswood	Holme Moss	169	272	698	58·2
(*h*)	Hookwood	Holme Moss	178	286	710	57·8

Fig. 2 - Variation of field strength with time

Table 4 gives the ratios of the field strength measured at Kingswood relative to Reigate, and at Kingswood relative to Hookwood for the two transmissions. The Reigate and Hookwood sites, which are screened by the North Downs in the direction of Holme Moss and Sutton Coldfield, received field strengths over the test period that are 10·5 to 14·5 dB lower than at Kingswood. The ratio of the 0·1% and 1% values ranges from 12·5 to 14·5 dB, whereas for 10% and 50% of the time the range is 10·5 to 13·0 dB. Tropospheric conditions for the smaller time percentages tend to favour propagation by quasi-specular reflexion rather than by scattering, and the higher field strength ratios for the smaller time percentages are probably accounted for by this difference in the mode of propagation. It would appear, therefore, that at Reigate and Hookwood the tropospheric reflected signals are arriving at an angle such that the North Downs are effectively attenuating the signal, the attenuation for the reflected signal being slightly greater than for the scattered field.

TABLE 4

Field Strength Ratio for Receiving Sites (Overall Period)

CURVES (FIG. 2)	FIELD STRENGTH RATIO FOR STATED PERCENTAGE TIME (dB)			
	0·1%	1%	10%	50%
(*a*) - (*b*)	13·0	13·0	12·0	12·0
(*c*) - (*d*)	12·5	13·5	12·5	10·5
(*e*) - (*f*)	13·0	13·0	10·5	11·5
(*g*) - (*h*)	14·5	13·5	13·0	11·0

The two days of highest signals in each of the two periods are selected for closer examination. The highest signals of the first period were received on 16th and 17th December 1961, and of the second period on 1st and 9th September 1962. The daily field strength ratios for the two sites for the usual time percentages of these two days are given in Table 5. This table confirms that the field strength ratio is in general maintained during periods of abnormal propagation, the ratio ranging from 9·5 to 17·5 dB. The median signals on these days of abnormally good reception are greater by between 7 and 26 dB than the overall median signal.

TABLE 5

Field Strength Ratio for Receiving Sites (Days of Abnormal Propagation)

DATE	RECEIVING SITES	TRANSMISSION	FIELD STRENGTH RATIO FOR STATED PERCENTAGE TIME (dB)			
			0·1%	1%	10%	50%
16th Dec. 1961	Kingswood/Reigate	Sutton Coldfield	13·0	12·5	13·0	12·5
17th Dec. 1961	Kingswood/Reigate	Sutton Coldfield	13·0	13·5	12·5	12·0
16th Dec. 1961	Kingswood/Reigate	Holme Moss	13·5	14·5	14·5	9·5
17th Dec. 1961	Kingswood/Reigate	Holme Moss	12·0	12·5	12·5	13·5
1st Sept. 1962	Kingswood/Hookwood	Sutton Coldfield	12·0	11·0	14·0	13·0
9th Sept. 1962	Kingswood/Hookwood	Sutton Coldfield	11·0	12·0	12·5	11·0
1st Sept. 1962	Kingswood/Hookwood	Holme Moss	16·0	17·5	14·5	15·5
9th Sept. 1962	Kingswood/Hookwood	Holme Moss	13·0	13·5	15·5	15·5

4.2. Site Variation Factor Measurements

In order to determine whether the Kingswood and Reigate receiving sites were representative of the areas in which they were situated, continuous field strength measurements were made at various locations in the vicinity, each of approximately 30 minutes duration. The ratio of the median of each of these measurements and the median for the same period at the appropriate permanent site was then calculated. The average of the ratios, known as the site variation factor (s.v.f.), was then found. This figure is the correction usually applied to a particular site to make the measured field strength correspond to 50% locations. To arrive at this factor, about fifteen to twenty temporary sites are usually measured within a radius of 5 miles (8 km) from the permanent base. In this case, however, as the screening effect of the North Downs was being investigated, the measurements were confined to limited areas on the northern (Kingswood) and southern (Reigate) sides of the Downs. The Appendix details the measurements for each transmission at locations in the vicinity of Kingswood and Reigate. The s.v.f.s are given in Table 6. It will be observed that the s.v.f. for Reigate was also used for Hookwood; it was not thought necessary to repeat measurements, because of the similar topography and proximity of the two sites.

TABLE 6

Receiving Site Variation Factor

TRANSMISSION	RECEIVING SITE	SITE VARIATION FACTOR TO NEAREST ½ dB (dB)
Holme Moss	Kingswood	-1·0
Holme Moss	Reigate	-2·0
Holme Moss	Hookwood	-2·0
Sutton Coldfield	Kingswood	+3·0
Sutton Coldfield	Reigate	-3·5
Sutton Coldfield	Hookwood	-3·5

To relate the field strength as measured to the average field strength for the area in the immediate neighbourhood of the permanent site, the figures of Table 6 should be applied as corrections to Table 3. The ratio of field strengths between the exposed and shadowed sites would then range from 11·5 to 19·5 dB as compared with 10·5 to 14·5 dB given in Table 4. The increase in the range of the ratio of field strength when applying the s.v.f.s is due to the Sutton Coldfield s.v.f. at Kingswood being +3·0 dB, whereas the other s.v.f.s vary from -1·0 to -3·5 dB. The s.v.f. measurements, however, show that the sites used for the main series of measurements are not subject to very local reception anomalies. For this report, therefore, the shadow loss is taken as the measured field strength ratio, that is, 10·5 to 14·5 dB.

4.3. Comparison of Measurements with the CCIR (Stockholm 1961) Field Strength/Distance Curves

The CCIR (Stockholm 1961) field strength/distance overland curves for Bands I-III, together with the measured fields for the appropriate time percentages obtained at Kingswood, Reigate and Hookwood, are reproduced in Fig. 3. The CCIR curves for an effective transmitting aerial height of 300 metres are used, as the heights of Holme Moss and Sutton Coldfield aerials above mean terrain are 318 and 299 metres respectively, for the particular transmission paths. It will be noted that the Kingswood values lie somewhat above the appropriate CCIR curves, while the Reigate and Hookwood values lie below. Agreement of some of the values with the CCIR curves is not good, but it should be borne in mind that the present measurements were taken at Band I frequencies, and over a short period of time, whereas the CCIR curves are derived from long-term data in the wider frequency spectrum comprising Bands I-III. The main point to be noted in Fig. 3 is the wide difference in the field strengths at the exposed and shadowed sites though there is little difference in the lengths of the paths.

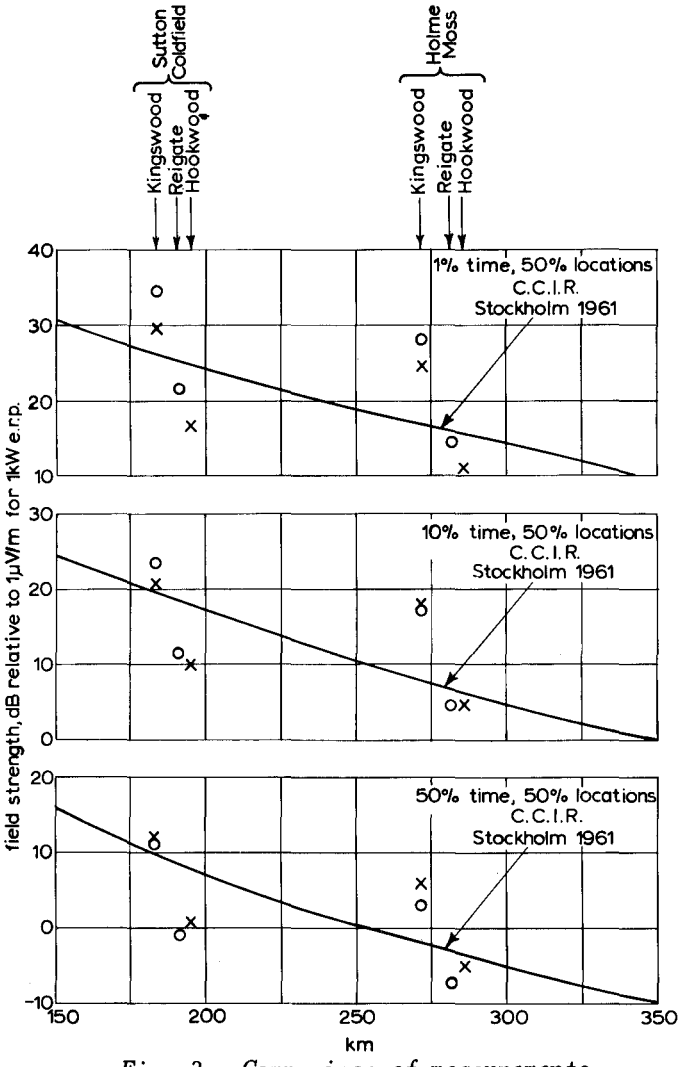


Fig. 3 - Comparison of measurements with CCIR (Stockholm 1961)

o measurements 1st Nov 1961 - 28th Feb 1962
x measurements 26th July 1962 - 20th Sept 1962

5. PREDICTION OF THE SCREENING EFFECT OF THE NORTH DOWNS

The CCIR curves in Fig. 3 show that due to the greater distance from the transmitter of the Reigate and Hookwood sites compared with Kingswood, the difference in field strength for average terrain is at most 2 dB. The measured field strength ratios range from 10·5 dB to 14·5 dB, and if a correction is made for distance, the ratios due to terrain alone lie between 8·5 dB and 12·5 dB.

If a relay station is required to serve an area which is screened by a range of hills in the direction of the co-channel transmitter, it is desirable that the shadow attenuation should be predictable without recourse to actual measurements.

One approach to this problem is to use the 'geometrical angular distance'[3] parameter, which takes account of the aerial heights and the terrain along the transmission path. Angular distance, θ, usually expressed in milliradians, is defined as the angle in the great circle plane between the radio horizon rays from the transmitting and receiving

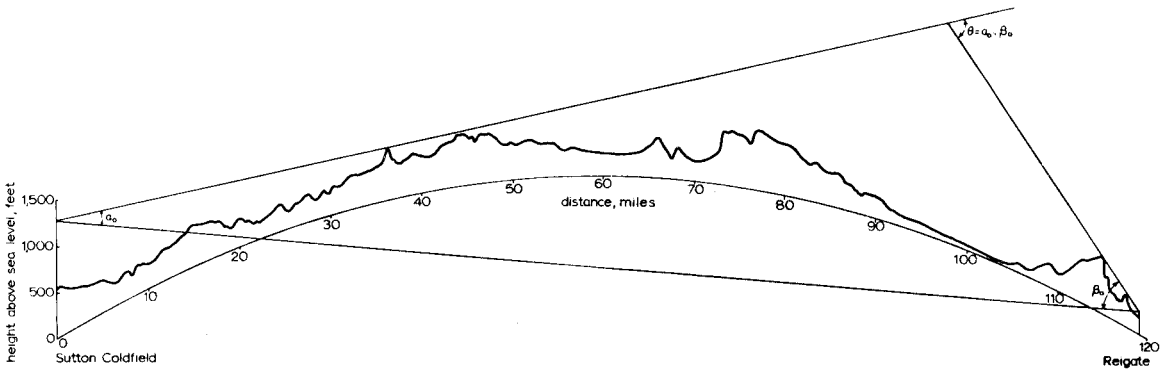


Fig. 4 - Sutton Coldfield-Reigate path profile

aerials. Fig. 4 shows the profile between Sutton Coldfield and Reigate and illustrates graphically the angular distance for this path. The profile is drawn on 4/3 earth's radius paper, because angular distance is defined on this basis.

The calculated value of angular distance for each path is shown in Table 7 and these, together with the appropriate field strengths in Table 3, were used to derive (by the method of least squares) the best fit line for each time percentage. Two laws were tried, one expressing field strength in decibels as a function of angular distance, and the other as a function of the logarithm of the angular distance. There is less scatter of the plots for the field strength against the logarithm of angular distance. The field strength, E, may therefore be regarded as varying with angular distance, θ, according to the inverse power law relationship $E = k/\theta^m$, where k is a constant taking account of terrain characteristics, effective aerial height and radiated power, and m is the slope of the 'best fit' line.

TABLE 7

Transmission Path Angular Distances

RECEIVING SITE	TRANSMISSION	ANGULAR DISTANCE, θ, IN MILLIRADIANS
Kingswood	Sutton Coldfield	14·0
Reigate	Sutton Coldfield	34·4
Kingswood	Holme Moss	20·2
Reigate	Holme Moss	49·2
Hookwood	Sutton Coldfield	28·9
Hookwood	Holme Moss	32·8

Fig. 5 gives the field strengths plotted against angular distance on logarithmic paper, along with the 'best fit' lines for the appropriate time percentages. The scatter of the measurements is greater for the 0·1% and 1% time values than for the 10% and 50% values. This is probably accounted for by the fact that

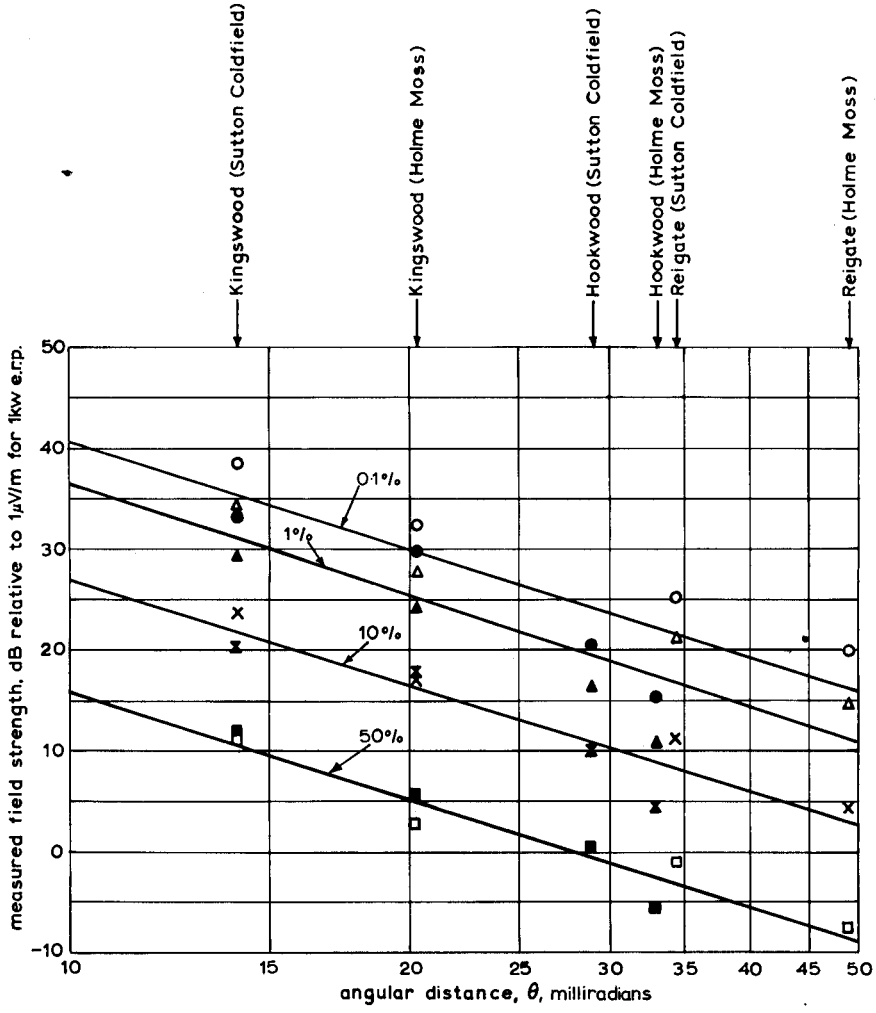


Fig. 5 - Variation of measured field strength with angular distance for fixed percentages of the time

○ 0·1%	Measurements 1st November 1961- 28th February 1962	● 0·1%	Measurements 26th July 1962- 20th September 1962
△ 1%		▲ 1%	
× 10%		⧗ 10%	
□ 50%		■ 50%	

abnormal propagation conditions which are represented by the 0·1% and 1% time values were more prevalent in the period 1st November 1961 to 28th February 1962 than in the period 26th July 1962 to 20th September 1962. On the other hand, the 10% and 50% time values are more representative of normal propagation conditions.

In the planning of relay co-channel transmitter services, it is necessary in Band I to take account of increased protection afforded by the terrain. The curves

of Fig. 5 give some indication of the order of increased protection available when the angular distances for two sites receiving the same transmission are different. For instance, to assess the increased protection available from terrain, the angular distance of the site in the shadow, and of a site on the hill immediately above it, may be calculated and the decibel ratio expected to exist between the field strengths at these two sites read from the appropriate time percentage curve of Fig. 5. If, however, the site on the hill is considered to be better than a '50% site', this implies that the added protection relative to the CCIR curve will be less than that indicated in Fig. 5. Some allowance should be made in such cases, but at the present time experience appears to be the best guide as to the actual allowance to make. The circumstances envisaged in this report are that the shadow loss is appreciably larger than such allowances.

6. CONCLUSIONS

An improvement in protection is obtained when receiving locations are screened from long-distance interference by hills. This is maintained during both normal and abnormal propagation conditions, with a slight tendency to increase in the latter case. This additional protection can be taken into account in planning Band I relay services, provided allowance is made (where necessary) for favourable terrain effects at the edge of the shadow area.

7. ACKNOWLEDGEMENTS

The Research Department staff concerned with the installation and maintenance of the apparatus and also with the analysis of the measurements were Messrs. S.J. Ashdown, I. Rhodes, J.C. Westhorp and Mrs. S. Dampney.

Thanks are due to Messrs. R.S. Sandell and L.T.E. Ward of the BBC Research Department who kindly permitted equipment to be installed at their private residences for this series of tests.

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3. 'The Use of Angular Distance in Estimating Transmission Loss and Fading Range for Propagation through a Turbulent Atmosphere over Irregular Terrain', K.A. Norton, P.L. Rice and L.E. Vogler, Proc. I.R.E., October 1955, Vol. 43, pp. 1488-1526.

APPENDIX

SITE VARIATION FACTOR MEASUREMENTS

Measurements made in the Kingswood Area

Transmissions from Holme Moss (48·25 Mc/s) and Sutton Coldfield (58·25 Mc/s)

TEST NO.	SITE LOCATION	GRID REF. (100 km SQUARE TQ)	SITE HEIGHT (a.m.s.l.)		DISTANCE FROM PERMANENT SITE		48·25 Mc/s			58·25 Mc/s			SITE DETAILS
							TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY SITE WITH PERMANENT SITE	TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY SITE WITH PERMANENT SITE	
			ft	m	ml	km	dB	dB	dB	dB	dB	dB	
1	Crossways Farm	263534	625	190	1·8	2·9	29·5	25·5	4·0	36·0	24·5	11·5	Few trees with falling ground in front for 1 mile, then rising.
2	Burgh Heath	241576	550	168	1·3	2·1	20·5	19·5	1·0	30·0	23·5	6·5	Level open space with small trees and houses in front.
3	A.24, North of Mickleham	169544	150	46	5·0	8·0	8·5	11·0	-2·5	22·0	25·5	-3·5	Clear site except for 30 ft trees.
4	Alderstead Heath	300551	550	168	3·3	5·3	20·5	23·0	-2·5	28·5	26·0	2·5	Small trees in vicinity. Ground falling slightly in direction of transmitter.
5	West Ewell	203634	100	30	5·5	8·9	10·5	17·0	-6·5	27·0	25·0	2·0	Slightly falling ground with trees one side of the road and houses the other.
6	Epsom	199608	200	61	4·3	6·9	5·5	9·5	-4·0	21·5	27·0	-5·5	Level ground with 40 ft trees 1/4 mile in front.
7	Mogador	240530	600	183	1·9	3·1	26·5	23·5	3·0	34·0	27·0	7·0	Terrain sloping away gradually, with trees at 200 yds distance.
Fixed Site	Kingswood	248559	550	168	Holme Moss (48·25 Mc/s) Site Variation Factor -1·1 dB					Sutton Coldfield (58·25 Mc/s) Site Variation Factor +2·9 dB			

(Field strengths are expressed in dB relative to 1 μV/m for 1 kW e.r.p.)

Measurements made in the Reigate Area

Transmissions from Holme Moss (48·25 Mc/s) and Sutton Coldfield (58·25 Mc/s)

TEST NO.	SITE LOCATION	GRID REF. (100 km SQUARE TQ)	SITE HEIGHT (a.m.s.l.)		DISTANCE FROM PERMANENT SITE		48·25 Mc/s			58·25 Mc/s			SITE DETAILS
							TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY SITE WITH PERMANENT SITE	TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY SITE WITH PERMANENT SITE	
			ft	m	ml	km	dB	dB	dB	dB	dB	dB	
1	A.23 North of Horley	283452	175	53	1·8	2·9	10·5	8·5	2·0	13·5	12·5	1·0	Flat, open site, ground rising very slightly in front of aerials.
2	Lodge Lane, Salfords	272461	190	58	1·0	1·6	10·0	7·0	3·0	11·0	12·5	-1·5	Open site, ground falling away slightly.
3	Woodhatch, 50 yds East of Angel Public House	259489	200	61	1·0	1·6	1·0	6·5	-5·5	6·5	13·0	-6·5	Site overshadowed by hill and houses.
4	75 yds from A.217	255494	362	110	1·4	2·3	8·0	8·5	-0·5	12·5	14·0	-1·5	Aerial pointing between houses. Ground falling for 1 mile, then high hill.
5	A.25 - Centre of Reigate	249503	260	79	2·1	3·4	2·0	7·5	-5·5	6·0	11·5	-5·5	Aerial pointing between houses but into hill.
6	North-West corner of Reigate	246512	325	99	2·7	4·3	1·0	6·5	-5·5	15·5	22·0	-6·5	Open site but aerial pointing into hill.
Fixed Site	Reigate	266476	180	55	Holme Moss (48·25 Mc/s) Site Variation Factor -2·0 dB					Sutton Coldfield (58·25 Mc/s) Site Variation Factor -3·4 dB			

(Field strengths are expressed in dB relative to 1 μV/m for 1 kW e.r.p.)

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey